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**PRINCIPLES OF SAFETY**  
**Safety in General, Criticality Risk in Perspective**

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## **PRINCIPLES OF SAFETY**

### **Safety in General, Criticality Risk in Perspective**

**My remarks will be divided into two halves--fundamentals of safety and fundamentals of accident prevention; then we will relate this second half to criticality. Let me delineate the fundamentals of safety:**

- 1. Management leadership in the declaration of policy and assumption of responsibility for control of accidents.**
- 2. Assignment of responsibilities to operating officials, safety and health personnel, supervisors, technical committees.**
- 3. Establishment of requirements for procedures, including review of procedures.**
- 4. Maintenance of safe working conditions: including inspections by specialists (cranes, elevators, high pressure equipment, fire protective devices, and so on), committee inspections, proper purchasing and acquisition, supervisory interest, and other elements.**
- 5. Safety training for supervisors and employees which could include first aid, emergencies, review of accidents, technical information, protective clothing, safety fundamentals, and a variety of specific subjects.**
- 6. Medical and first aid: preplacement and periodic examinations, treatment of injuries, health counseling.**

7. **An accident reporting and record system, including near misses or potential mishaps that can alert personnel concerned to needed protective measures or procedural changes.**

**Let us develop these elements of safety on a point-by-point basis.**

**The most important fundamental in the prevention of accidents is the assignment and the acceptance of responsibility. . . . where people such as you and I, at any level of supervision, or with staff assignments, say readily, "not only has this been assigned to me as an individual but I avow that if anything goes wrong in the operation with which I have been associated or assigned, come see me". This acceptance of responsibility seems universally to be rapidly fading away from the functions of modern administration which is unfortunate.**

**I emphasize the most important fundamental is the assignment and acceptance of responsibility. This responsibility must be accompanied by the authority and resources which are commensurate with the degree of responsibility expected.**

**Fifteen years ago at the Laboratory where I worked we had a series of devastating explosions. These mishaps cost the lives of six employees and left 28 fatherless children. The most common deficiency leading up to these accidents was the lack of appropriate operating procedures.**

When I spoke to people, some of my own people, reminding how remiss we have been in the steps available to avoid these catastrophies they said, "Oh, you asked them to have procedures, twice you asked them to have procedures". I would have done it 40 times and I still would have been remiss because I still had not exhausted all the resources available to me to prevent these mishaps from occurring. If you stand somewhere in the chain of responsibility for the performance of people and you have not exhausted all your resources, you share responsibility, you should accept responsibility, for what goes wrong. And the more you obsess yourself with this idea I believe the less are the chances that accidents will occur. Supervisors closest to the operations being performed, the first level of supervision, those closest to the employees carrying out the procedures, must have the assigned responsibilities. By the acceptance of this responsibility we say supervisors can then proceed to carry out the elements of a program necessary to control accidents. The management chain above the supervisors shares this safety responsibility, perhaps in a more limited way, but clearly their support is required in the many elements of the safety program: reiteration of policy, provision of resources, and the willingness to exert a heavy hand.

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We start off here with management leadership and the importance of assigned responsibility. It is very simple when management says "This is our establishment. We propose to proceed in a certain way. We want a certain level of safety". These cannot be left to words. Shakespeare in one of his King Henry works spoke of the king on the night before battle walking among the troops. The phrase that's used and is taken from the play speaks of "A little bit of Henry in the night". When we have management leadership as a policy which is printed on a piece of paper to give out to our new employees or recited by the personnel people who give a new employee an orientation program; are all great. But they are only words and cannot be left at words. They require not only management policy but also leadership, and participation. If safety is left to the safety people to do it, it's going to be done inadequately, poorly, and sometimes ineptly. When we have management leadership which does more than express a policy, more than just make statements, but which includes participation, then we have taken an important step towards safety.

Assignment of responsibility and acceptance of responsibility are things I hope I've made perfectly clear as far as my own feelings are concerned.

## Establishment of Procedures

The more hazardous an operation the more necessary it is that there be a procedure thought out ahead of time checked by competent higher authority, not by remote authority but by close and competent authority. The more hazardous the operation is the greater need for the procedure which is expressed by the people who do the work, reviewed by people who are competent in the work and endorsed by higher authority. Let's substitute now for the word hazardous. . . . because by no stretch of the imagination can we say that in the history of nuclear energy and the history of nuclear safety that we can fairly characterize criticality as a high risk. But we can substitute for the word "hazardous" the word "sensitive", the words "operation which can create tremendous public reaction" or we can substitute the word "expensive". So wherever we have the procedure which can be characterized by these extremes, the extremes of hazardous, expensive, severe public reaction, the more reason then exists for procedures which are thought out, reviewed, and approved. Having once been done clearly we agree how to arrive at these procedures. We did it in a thoughtful and considerate fashion. They were not given to us as though from Mr. Sinai, engraved in stone. They were procedures created by man. Therefore, they require a follow up on a periodic or nonperiodic basis so long as the procedures are viable. There are many ways for us to find our way to the proper path. Clearly not just one way,

there are many ways; I feel no great concern about consistency or conformity. They are problems with procedures but they should be looked at, reviewed, tested, checked, and so on. We will relate the establishment of procedures to things we will discuss later on.

I have mentioned safe working conditions and that, of course, is no simple subject. It means that we wish to build a safe establishment, to maintain a safe establishment and to continue to review that establishment by a variety of means to see that it stays at a safe level.

I hope no one will accuse me of dismissing physical inspections but the greatest need in accident prevention and in safety training is the management of people's behavior. I am not talking about psychology or inspirational matters, or slogans, but the most fruitful avenue in accident prevention is indeed the management of personal conduct and that's done through the route of procedures and here again through this route of safety training. Now the larger the establishment the more different bureaus it has. It has all kinds of safety and health people and criticality safety people and public relations offices and so on. There often are special personnel to do the safety training. However, the more of this training in the procedures in the fundamentals of the problems of criticality, the more that's done by people like the actual supervisor the better it will be done. Not only in the sense of technical accuracy and technical relevancy but in the fact

**that again it provides us with a little bit of this "King Henry in the night"  
where the immediate supervision is expressing its management leadership  
in safety training for these important procedures.**



## Accident and Incident Reporting

The accident experience in nuclear criticality is so limited that the few misadventures that have occurred do not permit any statistical analysis. Statistics in accident prevention are used mostly anyway to make favorable or unfavorable comparisons that seem to serve the personal purposes of the user.

Thoughtful and detailed analyses of descriptive reviews of accidents are perhaps more useful in establishing accident prevention techniques and standards.

There is much to be learned in the analysis of misadventures, sometimes termed "near incidents", which did not result in any loss or injury. These mishaps which are nonaccidents can be powerful tools in accident prevention, as warning agents and as alert signals that perhaps we have deficiencies in our processes, procedures, equipment, maintenance, training or supervision.

I am not unmindful of the problems and exacerbated reactions that seem to follow the reporting of even inconsequential misadventures. I recognize that often these reactions are self-serving rather than safety serving. However, I have to believe, and I have to teach, that accident information and near-accident information are powerful forces for accident prevention.

The second greatest tragedy of an accident is that it does not serve sufficiently to prevent future similar mishaps. Near-incident information can be often equally important.

As a safety engineer I realize that I cannot be just one of those who reaches his limited level of flowering by being one of the kind who recites to a second party the misfortunes of a third party and considers that recitation professional accomplishment.

I wish I could devise a clever scheme that would commend and reward those who willingly make available to their colleagues information on their own near mishaps. I know it is my responsibility to shield them from the irresponsible reactions of inept authorities who overreact to this kind of information. I realize I have not always been successful in providing this shield. However, I insist that such near miss information is such an important accident prevention tool it must not be hidden and lost.

### The Supervisor and New Employee Orientation

Safety training for a new employee is often started within an organization in a "new employee orientation program". This program is usually carried out by personnel department and perhaps the safety and health participate. These are good programs and they are a help to the supervisor by relieving him of many administrative details. I play a role in these programs myself; I do not turn this responsibility over to the personnel department because I feel I do it better and that I should do it. Still what I do in safety orientation for the new employee is not nearly as important as what the supervisor can do to impress the new employee.

The supervisor is closer to the employee and to the operation and can make the strongest impressions on the new employee.

### The Supervisor and the Industrial Physician

In modern industry there are medical procedures of pre-employment and pre-placement and periodic physical examinations. In some sensitive areas, for example, in handling fissile materials where nuclear safety might be a consideration there is often a requirement that the individual be certified for a critical duty assign-

ment; this certification is usually part of the periodic examination by the physician. That means the physician sees the employee perhaps once a year.

However, the supervisor sees the employee every day and is in the best position to judge whether any significant change is taking, or has taken, place. I am not suggesting that the supervisor need be trained in special medical or psychological techniques or that he make definitive judgment in these areas but he nevertheless can observe changes on a day-to-day basis that would warrant referral of the employee to the appropriate authority.

The point I am making again and again in various areas is that the supervisor should not leave to the physician, to the training people, to the safety people, the responsibility for the conduct and training of his employee.

All of these things add up to developing in an employee a sense of personal responsibility for safety.

### Technical Resource Committees

When one is a supervisor it is his job to direct and counsel the actions of others. The supervisor has the responsibility for the working conduct of his employees and presumably the authority to control this conduct. In turn, the supervisor is responsible to higher authority whose job is to support the supervisor with the resources, including technical, needed for proper performance.

In criticality safety there are a variety of technical resources such as: manuals and codes, operating limits, and nuclear criticality safety specialists. A specialist can advise, help, review and also monitor criticality activities. Whether or not there is a criticality specialist there could be a technical committee to help. There are really two types of committees, both useful and therefore both important.

One kind of a committee is an instrument of the supervisor; this is a broad term but I am trying to describe a committee which is formed by and for the supervisor to advise him. This is a local committee, close to the operation, who will review the operations for the supervisor and advise him. An outside technical member might be a member of such a committee but most of the committee would be local.

The second kind of a technical committee would be an instrument of management, a technical resource and review committee reporting to authority higher than the previous one described. Such committees can usefully be devised for operations like criticality, electrical safety, explosives, cryogenics, and reactors. They are used in those areas generally termed potentially hazardous or sensitive.

The management committee operates not only to help the supervisor but also to monitor his activities. This committee acts for the management which is neither able or competent to examine into the technical aspects of the operations.

The two kinds of committees, local and management, do different things and have different functions and they both can be very useful.

My summary words on committees is that they should be made up of the best people you can find who are competent in the subject with which they are expected to deal. The fact that these good people might also be busy people is not necessarily a disadvantage. If I can possibly do it I would try to pick as committee members those individuals who would not fall in love with their committee work; they should be otherwise too busy. I may be misquoted here but I want really good people on the committee. These by definition are busy people; when they devote time to the subject of being a technical resource they're going to be direct,

straightforward, and useful. They're not going to be excessively concerned with inconsequential details because they don't have the time for it and they don't have the inclination for it. I believe strongly in favor of a technical resource advisory committee and at the same time these committees must not dilute the responsibility of the supervisor. They provide him with technical counsel; either his own committee or the one above him. They monitor and report to higher management and they're very useful. However, I prefer busy people so that their committee assignment does not become their most important occupation; otherwise mischief will result.

### Safety Motivation

An individual's motivation for safety can be either directed or self-induced. The first is exclusively the responsibility of higher authority, the latter perhaps equally divided between management and the individual.

Directed motivation for accident prevention is brought about by up-dated documented procedures in the use of which employees are properly trained, continuously supervised and periodically checked. This directed motivation is enhanced by various arranged techniques for accident prevention which include: selected supervisors whose responsibility is clearly defined and accompanied by commensurate

authority, employees assigned for their ability and judgment, and a safe working environment.

Independent of directed motivation for safety is the personal motivation for preventing accidents which is the matter of self-preservation. This self-motivation depends primarily on understanding what kind of accidents can occur and what are the consequences.

It has been common practice in the technologies potentially of high hazard to go to considerable efforts to acquaint employees with consequences of misadventure. One, however, cannot equate the importance of self-induced safety motivation with directed safety motivation. A supervisor has no more right to rely upon an employee's feeling for self-preservation than he has to rely on the enveloping cloak of safety allegedly provided by detailed rules from remote authority. At least 90% of safety motivation must come from above.

#### Criticality Safety Data

The amount of criticality data is certainly growing steadily and they may still be need for more information. However, it was realized many years ago that there was sufficient criticality safety information available to permit safe management of fissile materials.



There is good historical evidence that sufficient theoretical knowledge about critical processes was on a sound basis before there even existed sufficient materials to cause a criticality accident.

The foregoing points to human behavior as the main problem of nuclear safety. Certainly there is no evidence that the state-of-the-art lacked criticality information in any of the few mishaps that have occurred.

Therefore, emphasis must be kept on the administrative aspects of nuclear safety and on the continuous application of sound and basic safety fundamentals for the management of nuclear facilities as one would do for any hazardous, or expensive, or sensitive operations.

### Special Problems

Every hazardous industry or industry with any unique risk has special safety rules or requirements not usually found elsewhere.

For example, in restaurants or any food preparation industries employees are trained and cautioned to wash their hands after going to the bathroom. When I first worked in the chemical explosive industry, particularly in acid manufacturing, I was cautioned that I should wash my hands before going to the bathrocm.

Criticality safety requires a knowledge of the fundamentals of its particular problems and the use of ones imagination in the avoidance of these same problems.

An example occurred in an enriched uranium processing plant a few years ago. The plant processed mostly solutions which were moved around in piping and reaction vessels that were ever-safe geometries. The supervisor entered the processing area one day and noticed that an employee had placed a pail under a leaking joint to catch the solution which was leaking on the floor. Of course this was collecting the solution in a different geometry. The supervisor immediately established and posted a safety rule "DANGER - Leaks MUST Be Allowed to Drip on the Floor". Here is an example of a "near nonaccident" providing important information to an imaginative supervisor and thus contributing to the safety of the operations.

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## Early Accident History

It is the historic nature of new technologies to become safer with acceptance or, conversely, to gain acceptance as they become safer. As experimental science is an adventure form, it has been all too common, particularly in the comforting wisdom of retrospection, for unnecessary risks to be taken to enjoy direct observation. One does not have to go back to the valiant experimenters of the 19th Century (Gay-Lussac and others; the natural philosophers who insisted on touching, smelling, tasting, and self-experimentation). As recently as the 1960's, the brilliant investigators of noble gas compounds received severe injuries in their work with unstable xenon salts. If we go back to the early days of research with significant quantities of fissile materials we can find direct observation accidents.

In one case a critical assembly was being created by hand stacking 4.4 kg tungsten carbide bricks around a plutonium core. The core was a 6.2 kg sphere. The experimenter, working alone, was moving the final brick over the assembly. He noticed from the nearby neutron counters that the assembly of this brick would make the assembly super-critical. As he withdrew his hand the brick slipped and fell onto the center of the assembly. This additional reflection made the system super prompt critical; the resulting power excursion had fatal consequences to the individual.

In a second incident, a demonstration was held to show several people the techniques involved in creating a metal critical assembly. The system consisted of the same core described earlier but reflected in this case by beryllium. The top and final Be shell was being lowered slowly into place; one edge was touching the lower beryllium hemisphere while the edge 180 degrees away was resting on the tip of a screwdriver. The person conducting the demonstration was holding the shell with his left hand with the thumb placed in an opening at the polar point, while slowly working the screwdriver out with his right hand. At this time the screwdriver slipped from under the shell and the shell fell completely on the lower hemisphere. The resulting power excursion gave a lethal radiation dose to the demonstrator.

These incidents should be only of historic interest now as the techniques employed then would not be considered today. To use these early accidents as examples of the need for more restrictive measures is to deny the evolution of science. As recently as the 1950's I reviewed a draft of a proposed set of specifications for motor vehicles carrying hazardous cargo. Someone had specified that the "lighting system for such vehicles shall be electric". After puzzling over this for a short time I realized that someone had learned from regulations written shortly after 1920 which forbade the practice of motorized vehicles using acetylene lamps when carrying hazardous cargo.

**Conclusion**

My closing remarks are directed to those of you with responsibility for the accomplishment of others--for their work, their programs, their successes and their failures, their safety and their accidents.

Do you really know what your people are doing and how they are doing it?

Do your people know the nature and consequences of misadventure?

Have you provided sufficient guide lines for a safe level of performance - instructions, safe operating procedures, safety manuals or guides? In the words of Laennec, great physician and inventor of the stethoscope, "Do not fear to repeat what has already been said. Men need the truth dinned into their ears many times and from all sides. The first rumor makes them pick up their ears, the second registers, and the third enters."